P-22: Hydrodynamic and X-Ray Physics

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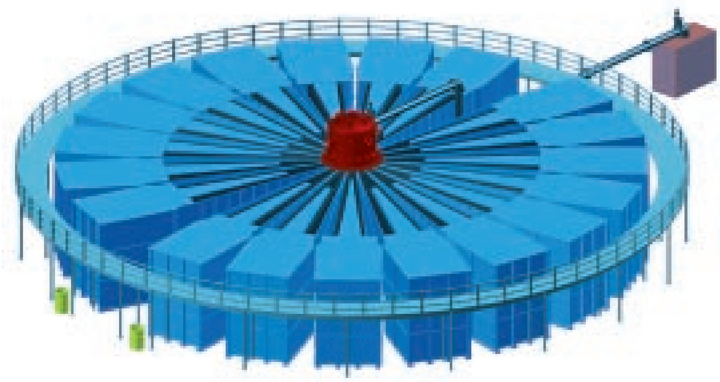
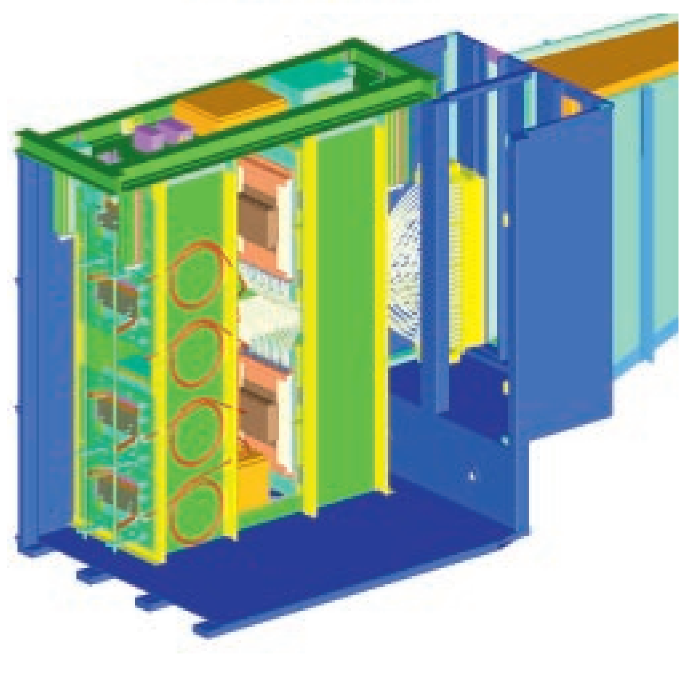
Introduction

The mission of the Hydrodynamics and X-Ray Physics Group (P-22) is to solve challenging experimental physics problems relevant to our national security, particularly when we can reduce the threat of war by helping to ensure the reliability of our nuclear-weapons stockpile and by limiting the proliferation of weapons of mass destruction. We continue to maintain and develop as national assets a creative, multidisciplinary team and state-of-the-art technology. To fulfill its mission, the group maintains a broad physics and engineering capability and pulsed-power facilities. Physics disciplines include hydrodynamics, x-ray spectroscopy and imaging, plasma physics, radiation hydrodynamics, optics and fiber optics, microwaves, electromagnetics, atmospheric physics, and atomic physics. Engineering disciplines include analog and digital electronics; electro-optics instrument design and fabrication; high-voltage, low-inductance, pulsed-power engineering; and fast-transient data recording. P-22 is the home of the Pegasus II Pulsed-Power Facility and of the future Atlas High-Energy Pulsed-Power Facility (Fig. I-4).



(a)



(b)

Fig. I-4. (a) Detail of the heart of the design for Atlas, showing oil tanks (in blue) that will hold the Marx units, the troughs containing the transmission lines (in black), the target chamber (in red at the center), and the vacuum line and evacuation system (the black pipe leading to the brown tank). Each of the oil tanks will contain thirty-two 60-kV capacitors. The two 55-gal. tanks on the left show the size of the designed machine. (b) Cross section of the lower half of one of the maintenance units, showing four large capacitors and the isolation switches for each pair of capacitors.

Nuclear-Weapons Program Research

The mainstay of P-22 has been its support of the nuclear-weapons program. P-22 applies the scientific and engineering expertise that it developed for the nuclear test program to investigate and understand crucial weapons-physics issues in a world without nuclear testing. The foundation of the present Los Alamos nuclear-weapons program is Science-Based Stockpile Stewardship (SBSS), which requires the development of complex experiments on diverse facilities to address the relevant physics issues of the enduring stockpile.

P-22 continues to field experiments underground at the Nevada Test Site (NTS), both to maintain our readiness to support a resumption of nuclear testing, should the need arise, and to study the physics of weapons performance and materials. These experiments increase our understanding of weapons science by allowing improvements in code calculations and in estimates of the severity of problems and changes occurring in the nuclear stockpile as it ages. At present, we are fielding experiments to measure the equation-of-state properties and spall strength of weapons-grade plutonium. We are also designing experiments and developing diagnostics to measure the properties of material ejected when plutonium is shocked by a high-explosive detonation. By performing these experiments underground at NTS, the plutonium is handled and contained in a manner similar to that used for underground nuclear tests.

In the portion of the weapons program involving above-ground experiments (AGEX-1), we are developing diagnostics to study the physics of the release of high-pressure shock waves. Diagnostics under development include the following:

- visible-wavelength and infrared pyrometers to determine the temperature history of a shocked surface;
- a very-short-pulsed laser and an ultrafast streak camera to determine by elastic backscattering the density and size of an ejecta cloud of fine particles, particularly when the particles are too small to be identified by holography;
- low-energy x-ray sources for imaging of low-density material from shocks;
- a reflectivity diagnostic to determine whether the surface of a shocked sample has melted; and
- a measurement of the speed at which moving, high-density material can produce a fiber-optic signal.

These diagnostics will be used to study shocks produced by explosives, gas guns, and the Pegasus capacitor bank.

In other AGEX-1 work, we are supporting the development of the Dual-Axis Radiographic Hydrotest Facility (DARHT) by studying the beam physics of DARHT's technical precursor, the Integrated Test Stand (ITS). We have built and fielded a magnetic spectrometer to measure the beam energy as a function of time in the 70-ns ITS pulse. We are developing a microwave diagnostic to measure nonintrusively the beam electron density, and we are participating in the planning of new advanced radiographic facilities. We built and tested an elastic-backscattering lidar system that can find, track, and map out the shape of the effluent cloud from a small high-explosive detonation miles away, even when the cloud is invisible. The lidar can direct equipment, such as a remotely piloted airplane, to sample the effluent cloud to determine the presence of hazardous materials.

As part of the High-Energy-Density Physics (HEDP, formerly AGEX II) program, the 4.3-MJ Pegasus II Pulsed-Power Facility is used to drive experiments in which the weapons community is interested. Pegasus II can be used as a radiation driver or as a hydrodynamic driver in convergent geometry. Experiments are being performed to investigate nonsymmetric hydrodynamic flow and ejecta formation of shocked surfaces. In addition, pulsed-power research on improved radiation drivers, fast vacuum switching, and power flow channels are being pursued as we look to the future requirements of Atlas and explosive pulsed-power systems. P-22 has provided pulsed-power and diagnostic expertise to Procyon, Ranchito, and Ranchero, the Laboratory's high-explosive pulsed-power systems.

P-22 is the home of Atlas, the next-generation 36-MJ pulsed-power facility. The year 1996 marked the official start of the Atlas construction project, with the first dollars arriving for detailed facility design. Atlas will provide advanced radiation and hydrodynamic capabilities for weapons-physics and basic research. Research and development activities have centered on component development, prototype design and testing, and investigation into how the physics of interest scales to higher energies. The present design would provide operation at 240 kV, 480 kV, and 960 kV, allowing a wider scale of experiments to be performed than in earlier conceptual designs.

P-22 is deeply involved in protecting and archiving the volatile test data it took during more than three decades of underground nuclear testing. Our goal is to bring the group's data to a stable and readily accessible state. These data will be used to benchmark all future calculational tools.

In another part of the HEDP program, P-22's plasma-physics expertise and ability to do large-scale integrated experiments have provided group members with the opportunity to participate in several collaborations with the premier All-Russian Institute of Experimental Physics at Sarov, Russia (VNIIEF), the weapons-design laboratory that is the Russian counterpart of Los Alamos. In addition to giving us the chance to learn about some of the Russians' unique capabilities, the collaborations provide Russian weapons designers with an opportunity to do peaceful basic-scientific research and to integrate themselves into the world's broader scientific community. These collaborations are based on our mutual interests in high-explosive-driven pulsed power, wherein the Russians have clearly demonstrated scalability to large systems that is unmatched to date in the United States. P-22 is participating in experiments on the Russian MAGO system, a possible candidate for magnetized target fusion; in attempts to convert a frozen rare gas to a metal by compressing it in a large magnetic field; in the design and testing of a thin, imploding cylinder for a megajoule x-ray source; and in studies of the properties of materials at cryogenic temperatures in magnetic fields up to 1000 T.

The group has two vacuum ultraviolet beamlines and two x-ray beamlines at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL). These beamlines, which cover the photon energy range from 30 eV to 20 keV, are used to calibrate detectors and to pursue research. Over 100 detectors were calibrated for use in HEDP experiments this year. Presently group members are studying electron-electron interactions in atomic systems by measuring the multiple ionization in rare gases near their respective K-edges. These measurements require the tunability and resolution of the synchrotron x-ray source to further delineate the limitations of the one-electron model.

Technology Transfer

P-22 has increased its involvement in technology transfer with several cooperative research and development agreements (CRADAs). Our knowledge of Faraday fiber-optic sensors is being applied to provide active feedback of the speed of the wheels of large trucks during braking. This work has recently been submitted for a patent. A debris-free, electron-beam-driven lithography source at 130 Å is being developed in conjunction with LANSCE Division and Northrup Grumman Corporation. This effort is an attempt to use the predicted anomalous energy loss of a short-pulse (subpicosecond) electron beam in a preformed plasma to heat and further ionize the ions to a charge state such that efficient 130-Å emission will occur.

Challenging engineering problems must be solved for experiments to succeed. Such challenges include the remote control of instrumentation, specific instrument performance, and package design for both laboratory and field environments. P-22 has an in-house capability to design, prototype, and characterize new components and systems with specialization in microelectronics, high speed, and optoelectronics. Industrial interactions include work with IBM and Motorola through CRADAs and funds-in agreements.

Our integration of broad experimental physics and engineering expertise enables the group to fulfill its mission and opens the door to exciting future opportunities.